Refractive Index Contrast and Wavelength Dispersion of Channel Waveguides Inscribed by fs-Laser Induced Ion-migration Revealed by Imaging Ellipsometry

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In recent years fs-laser induced local modification of the glass composition has been shown to provide an extremely efficient alternative for the production of high performance passive waveguides, waveguide optical amplifiers and lasers [1,2,3,4]. We have shown that in several glass families including phosphates [3], tellurites [5], and borates [6] it is feasible producing high contrast waveguides by inducing the migration of an *index carrier element* (La, Te,…) towards the guiding region by fs-laser irradiation at high repetition rate. In the context of the aforementioned applications in amplification and lasing, it is important to know the wavelength dependence of the refractive index contrast ($\Delta n(\lambda)$) of waveguides produced by fs-laser assisted ion migration. There are some works that suggest that it should be is small, however there is a lack of experimental measurements of the actual dispersion of the refractive index of the waveguides. This is because measurement of the refractive index of micron-sized optical inscribed waveguides inside a dielectric is a challenging task. Different methods are used to determine the refractive index contrast, among them those based on the refracted near field determination (RNF) are the ones providing the best resolution. However, most of such methods do not provide spectroscopic analysis, which hinders the knowledge of the index dispersion of the waveguide, an essential parameter.

In this work, we demonstrate the successful determination of the refractive index as a function of the wavelength in the spectral region of 250-1700 nm for channel waveguides produced by fs-laser induced ion-migration in P_2O_5-La_2O_3-K_2O-based glass by using imaging ellipsometry. The results show that the inscribed waveguides have a high refractive index contrast with a diameter in the 25 μm range. SEM-EDX compositional analysis shows that in this glass waveguides are formed due to an enrichment in La_2O_3 in the topmost part of the laser excited region which is accompanied by the cross migration of K_2O towards the region underneath. Interestingly, the index contrast of the waveguides shows a largely wavelength independent behavior in the studied VIS-IR spectral region. We will discuss how this behavior can be related to the fact that in the analyzed compositional range, La^{3+} ions linearly contribute to the glass polarizability due to the relatively large mass of La^{3+} ions and the relatively small size of the isolated La-polyhedra accommodated in the phosphate glass network [7].

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